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USER MANUAL FOR REFRIGERATION SYSTEM MONITOR

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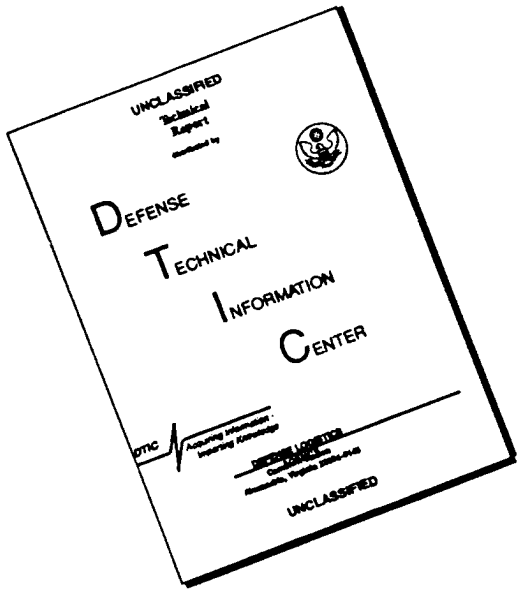

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A refrigeration system monitor has been developed which will provide an early warning that a refrigeration or air-conditioning system is experiencing internal problems. The monitor separates non-condensable gases from the flowing refrigerant and provides an external signal when a significant amount of gases have been collected. The presence of these non-condensable gases indicates that one or more problems are developing, including incomplete evacuation, suction side leaks and compressor bearings operating in a boundary lubrication regime. The type of gas collected is indicative of the specific malfunction. This document provides detailed instructions for the user regading installation and operation of the monitor.

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Figures

1.0 GENERAL PURPOSE OF THE MONITOR

The non-condensable gas (NCG) Monitor is designed to separate non-condensable gases from the flowing refrigerant in a refrigeration or air-conditioning system.

Non-condensable gases are undesirable in a refrigeration system under normal operation conditions, and their appearance is an indication of possible future system failures. Sources for non-condensable gases and their composition are:

- incomplete evacuation resulting in air, nitrogen or argon as non-condensable gases;
- low side leak resulting also in air, nitrogen or argon as non-condensable gases;
- motor / compressor stress reaction products :
    a) from motor insulation resulting in CO, CO_2, N_2, .. as non-condensable gases;
    b) from lubricant resulting in H_2, CH_4, C_2H_6, or CO and CO_2 for POE lubricants as non-condensable gases;
    c) from lubricant / bearing failures resulting in H_2 as non-condensable gases;
    d) from refrigerant reaction resulting in CO_2, HCl, HF.

In any case, the appearance of non-condensable gases is an indication of improper operation. The purpose of the non-condensable gas Monitor is

- to collect these non-condensable gases;
- to indicate that non-condensable gases have been collected;
- to provide a sample of the non-condensable gases for analysis.

Improper operation of the refrigeration or air-conditioning system will be indicated by the non-consensable gases collected by the Monitor, and steps can be taken at an early stage to avoid severe failures such as motor burn out or excessive increase of lubricant acidity and associated failures.

1.1 Functional Principle of the Monitor

The collection of the non-condensable gases is a separation process. The separation of the non-condensable gases from the circulating refrigerant takes place in a separation coil as shown in Figure 1.

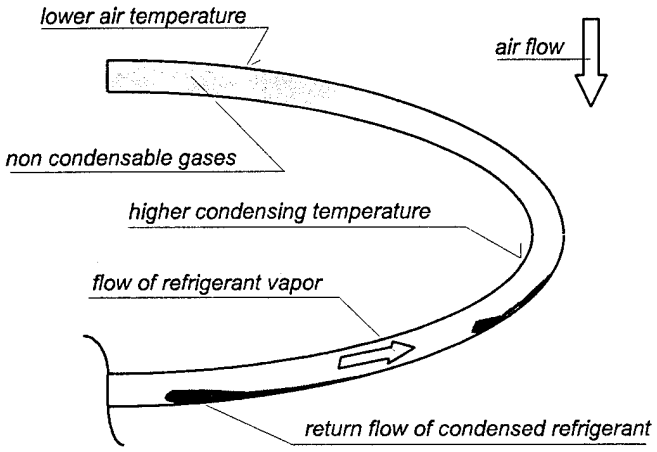


Figure 1: Section of the Separation Coil

Small amounts of refrigerant vapor at condensing pressure and temperature are constantly liquified in the coil. The coil is cooled by the same air, or air of lower temperature than is used for condensation of the circulating refrigerant in the condenser. The non-condensable gases will remain in the coil and collect at the top end. Once non-condensable gases are collected, the refrigerant condensation process will cease in this (top) section of the coil. Thus, with interrupted heat flow from the top section of the coil to the air, the temperature measured at this section of the coil will reduce to the air temperature. In the remaining (lower) section of the coil, where no non-condensable gases have collected, the temperature of the coil will remain at the higher condensing temperature.

The separation coil is part of the separation unit schematically shown in Figure 2. In this unit an additional coil is used for desuperheating and partial condensation of the hot discharge gas. A sight glass is used to control the flow and to confirm existence of two phase flow.

The needle valve is used to adjust the flow rate in a way that sufficient two phase flow will occur in typical operation conditions. Once this valve has been set, further adjustments are not necessary.

Only a small fraction of the total circulating refrigerant mass is condensed in the separation coil, since for proper operation, it is sufficient to feed only a fraction of the discharge gas through the separation unit of the Monitor (which encloses the separation coil). The separation unit of the Monitor is installed parallel to the discharge line between the compressor and the condenser or to a part of this discharge line.

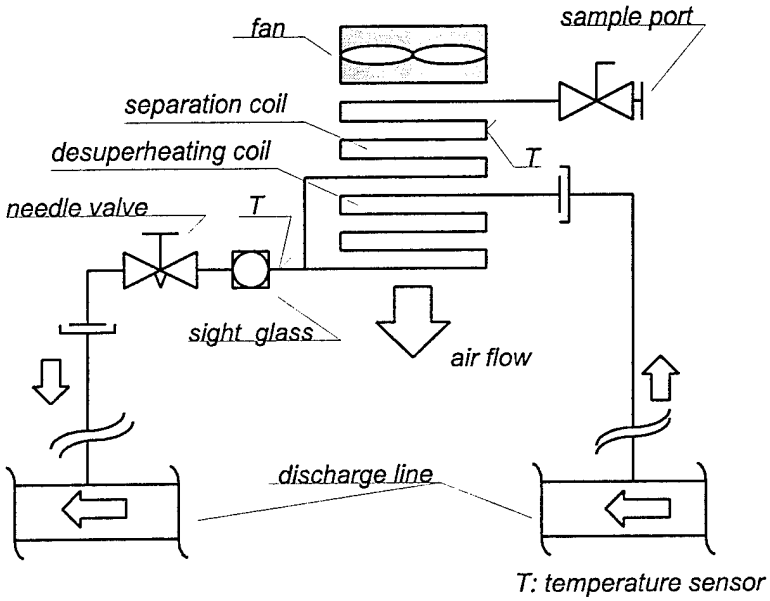


Figure 2: Schematic View of Separation Unit Installed Parallel to the Discharge Line

Two temperature sensors are installed in the separation unit. One is to determine the temperature at the upper part of the separation coil, and the other is installed at the end of the desuperheating coil close to the sight glass to determine the saturation temperature.

If the difference between the temperature measured at the separation coil and the temperature at the other sensor exceeds a certain level for a certain period of time, a collection of non-condensable gases will be indicated by the Monitor controller. Further increase in temperature difference and time will produce an audible alarm.

1.2 The Components of the Monitor

The Monitor consists of two major parts:

- the separation unit shown in Figure 3 and
- the controller shown in Figures 4a and 4b.

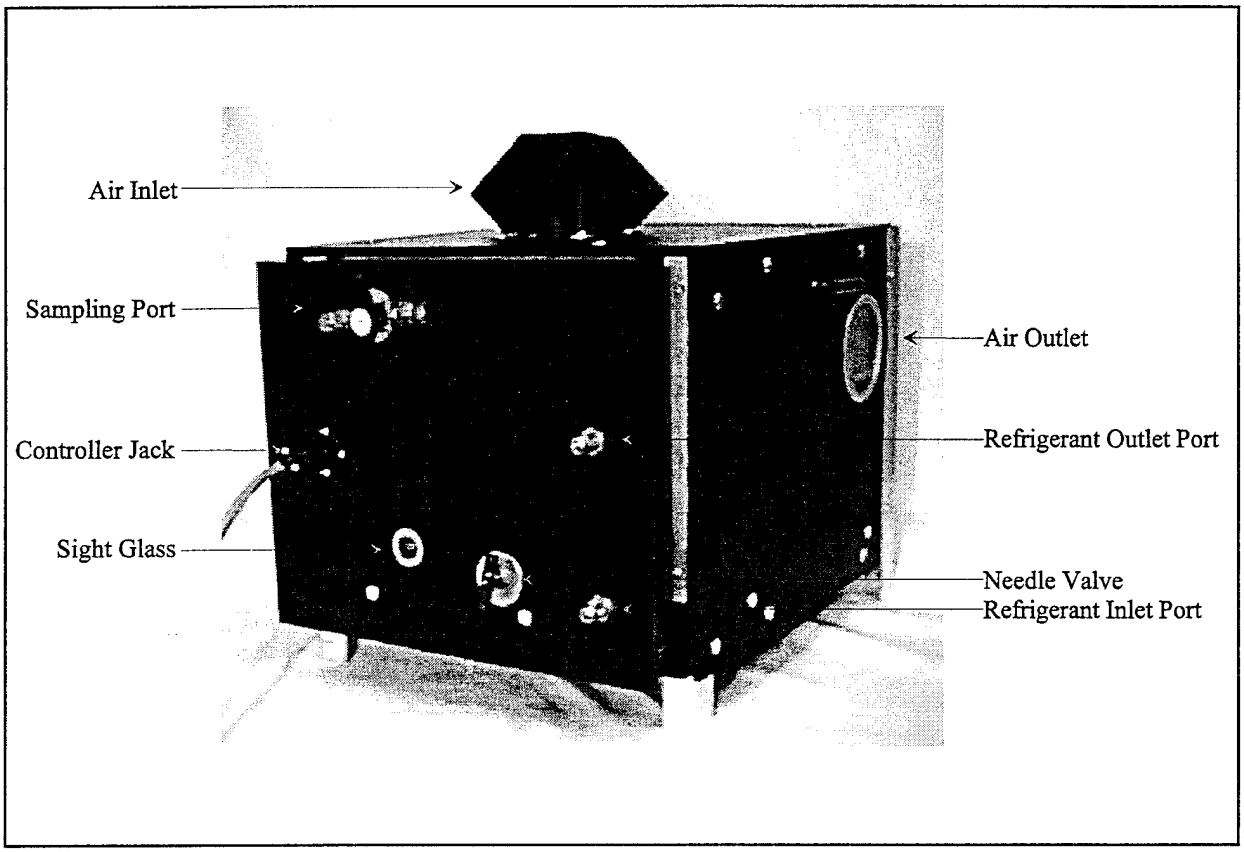


Figure 3: Separation Unit

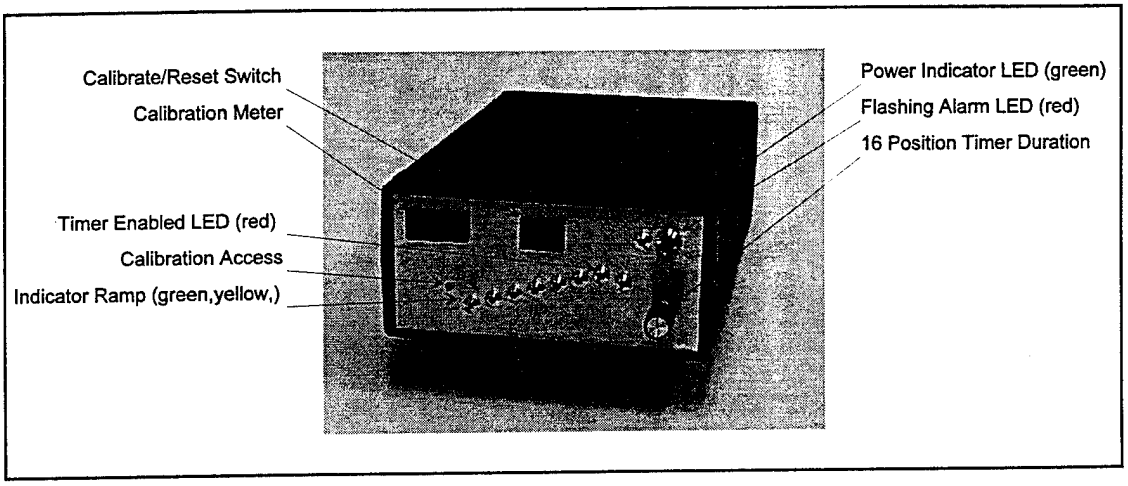


Figure 4a: Front View of the Controller

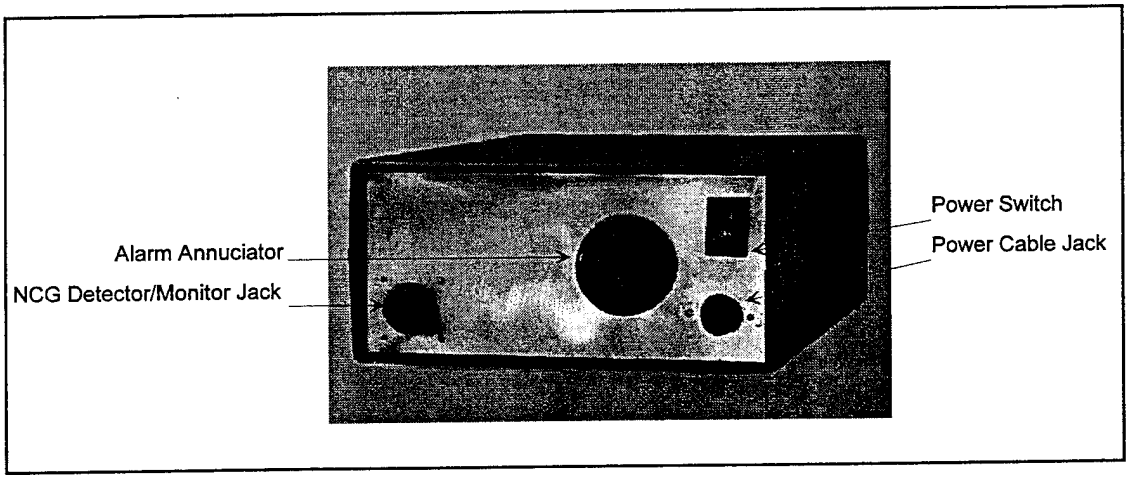


Figure 4b: Rear View of the Controller

1.2.1 Separation Unit

The separation unit as shown in Figure 3, contains the following components:

1. the separation coil for the separation of the non-condensable gases (1/4" stainless steel tubing);
2. the desuperheating column for desuperheating and partial liquefaction of hot discharge gas from the compressor (1/4" copper tubing);
3. the sight glass for visual control of two phase flow;
4. the needle valve as flow restrictor;
5. the refrigerant inlet port (1/4" male flare fitting) as connection port to the compressor side of the discharge line, or to a by-pass section of the discharge line;
6. the refrigerant outlet port (1/4" male flare fitting) as connection port to the condenser side of the discharge line, or to a by-pass section of the discharge line;
7. the fan for air circulation;
8. a thermostatic switch and a temperature sensor to contol the airflow through the fan (or to take the fan out of operation if the discharge temperature is low, and thus avoid full condensation in the desuperheater coil);
9. an air intake port;
10. three air outlet ports (right side, left side, rear);
11. temperature sensor (type Motorola MTS102) to determine the temperature at the upper part of the separation coil;
12. temperature sensor (type Motorola MTS102) at the end of the desuperheating coil to determine the saturation temperature;
13. jacks for connection of the sensors and the power supply with the controller;
14. sliding platform for easy maintenance.

1.2.2 Controller

The controller as shown in Figure 4, contains the temperature sensor signal processor. The temperature sensors have a linear response to temperature. The signals received from the two sensors are processed in the following order:

- Individual sensor 20 dB amplification.
- Analog differential 20 dB amplification.

- Variable amplification of 17 to 27 dB.
- Positive response limiter and minimum threshold conditioner .
- Variable trigger-point ladder detector with visual output.
- Count-down timer with 16 preset periods, pause, and reset

An indicator ramp of green and yellow LED's on the front panel of the controller housing indicates increasing or decreasing signal level. A red LED indicates when the timer has been enabled. A flashing red alarm light on the front panel and an audible alarm annunciator are actuated to indicate collection of sufficient non-condensible gases to warrant alarm conditions. The timer duration can be selected with a 16 position switch on the front panel.

A single switch on the front panel is used for calibration (left position) and reset (right position). A digital meter facilitates calibration.

Power switch, power cable jack, and separator unit jack are installed on the rear side of the controller housing.

1.2.3 Additional equipment

A 12V DC power supply is supplied with the Monitor as well as a 15' cable for the connection between the separation unit and the controller. The power supply operates from 115 VAC power.

The refrigerant piping needed for the installation of the separator is standard equipment, and must be provided on-site by the user.

1.3 Installation

The separation unit must be installed close to, and between, the refrigeration system compressor and condenser. A schematic view is given in Figure 5. The inlet port must be connected to the discharge line close to the compressor or directly to the compressor; 1/4" O.D. copper tubing is sufficient. This line must be insulated to prevent condensation in the tubing due to excessive heat loss.

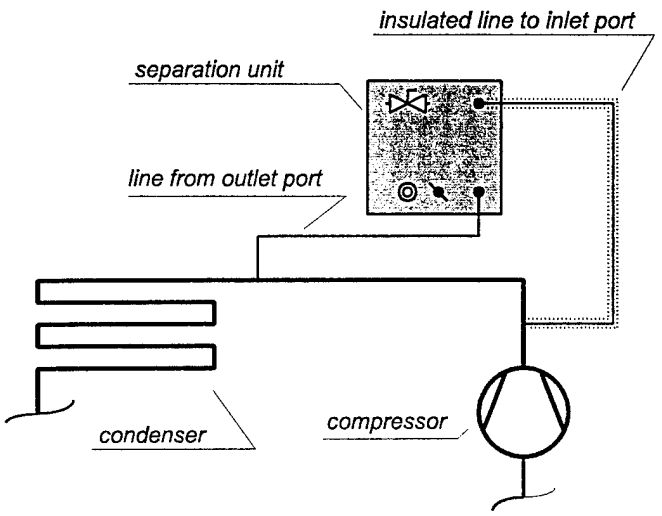


Figure 5: Schematic View of the Connection to the Refrigeration Cycle

The outlet port must be connected to the discharge line near the condenser inlet; again 1/4" O.D. copper pipe is sufficient, but insulation is not needed on this connecting line. The by-passed part of the discharge line should not be too short as a certain small value of pressure drop is needed to establish sufficient flow through the separation unit.

It is important for the Monitor to be physically positioned above the system connection points, in order to insure proper flow of refrigerant.

It is recommended that the needle valve of the separation unit be fully open during leak testing, evacuation and filling. Proper refrigerant reclaim, leak testing, evacuation and charging methods must be adhered to according to Federal guidelines.

The temperature of the cooling air at the air intake must be the same or lower than the tempearture of the air cooling the condenser.

The controller and the separation unit must be connected with the connection cable and the controller connected to the power supply.

1.4 Calibration

Due to the need for an isothermal environment, it might be necessary to calibrate the Monitor before the installation of the separation unit. The calibration is done according to the following procedure:

1. The separator unit and the controller should be placed in an isothermal area.
2. Install cables and turn on detector.
3. Let stand in the invironmen for 1 hour.
4. Push and hold calibration switch (Figure 4a) to the left.
5. If reading on the calibration meter (Figure 4a) is between +10 and -10 the unit is ready for use.
6. If reading is greater than +10 or less than -10, while holding the calibration switch to the left, adjust the meter reading with a screw driver through calibration access hole on front panel.
7. Allow 3 minutes for stabilization and repeat from step 5.

1.5 Operation

After the Monitor has been installed and calibrated as described, it is ready for opeation. Set timer logging function for one of the 16 possible durations as shown in Table 1 (position E, 1800 minutes, is a good starting position). Pushing the reset toggle (right) will initialize the time accumulator. When the differential temperature exceeds the preset limit (which has been factory set and requires no adjustment), the timer runs until the alarm sounds or the temperature falls below the limit. In the latter case, the elapsed time reading is discontinued until the limit is once more exceeded.

The presence of non-condensable gases is visually indicated by an ascending ramp of LED's (see Figure 4a). The topmost LED (red) is tied to the timer function, and the alarm condition is indicated by a pulsing siren and a flashing red LED. This indicates an appreciable quantity of non-condensable gases has been collected and can be captured for analysis. Purging without analysis is not recommended since valuable information will be lost, in addition to an intentional venting of regrigerant gas to the amtosphere.

Table 1: Timer Settings and Durations

0	1	2	3
7 SEC	13 SEC	26 SEC	52 SEC
4	5	6	7
105 SEC	211 SEC	7 MIN	13 MIN
8	9	A	B
28 MIN	56 MIN	112 MIN	225 MIN
C	D	E	F
450 MIN	900 MIN	1800 MIN	3600 MIN

1.6 Sampling for Analysis

The sampling port has a 1/4" male flare fitting connection. The sampling arrangement as shown in Figure 6 must be connected to this sampling port. The sampling procedure is:

1. Connect the sampling unit (3" to 5" 1/4" tube with two hand valves) to the sampling port of the separation unit;
2. Leak test;
3. Connect the second hand valve to a vacuum pump;
4. Evacuate the arrangement, while the hand valves of the sampling arrangement are both open and the sampling port valve on the Monitor is still closed;
5. After evacuation, close the valve connected to the vacuum pump;
6. Open the sample port valve on the Monitor;
7. Quickly close the hand-valve on the sampling unit;
8. Close the sample port valve on the Monitor;
9. Disconnect the sampling unit from the Monitor and the vacuum pump. Securely cap the flare fittings.

For analysis and evaluation of results Spauschus Associates, Inc. may be contacted.

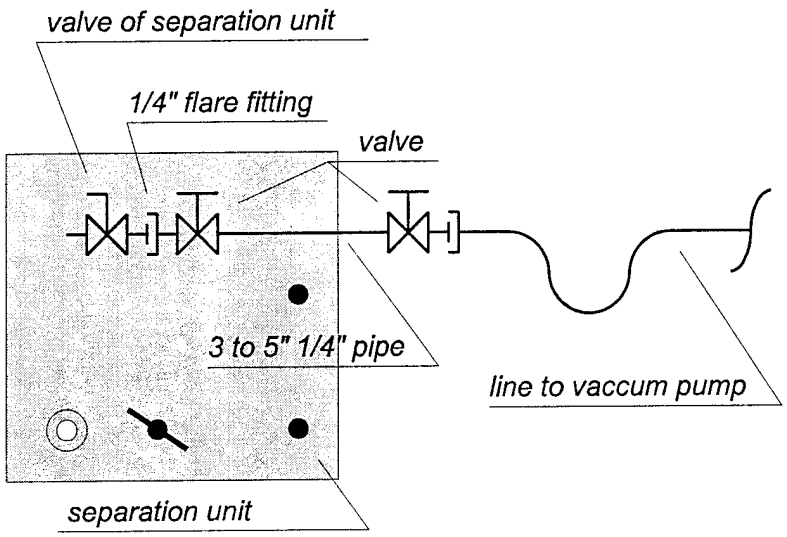


Figure 6: Arrangement for Sampling

1.7 Limitations of Application

This Monitor has been developed for air cooled refrigeration systems operating with single component refrigerants. For operation with refrigerant mixtures which show a significant temperature glide during evaporation and condensation, or for operation with liquid cooled units contact:

Spauschus Associates, Inc.
300 Corporate Center Court
Stockbridge, GA 30281
Tel.: 770 507 8849 Fax: 770 507 9247

1.8: Detailed Views of Separation Unit

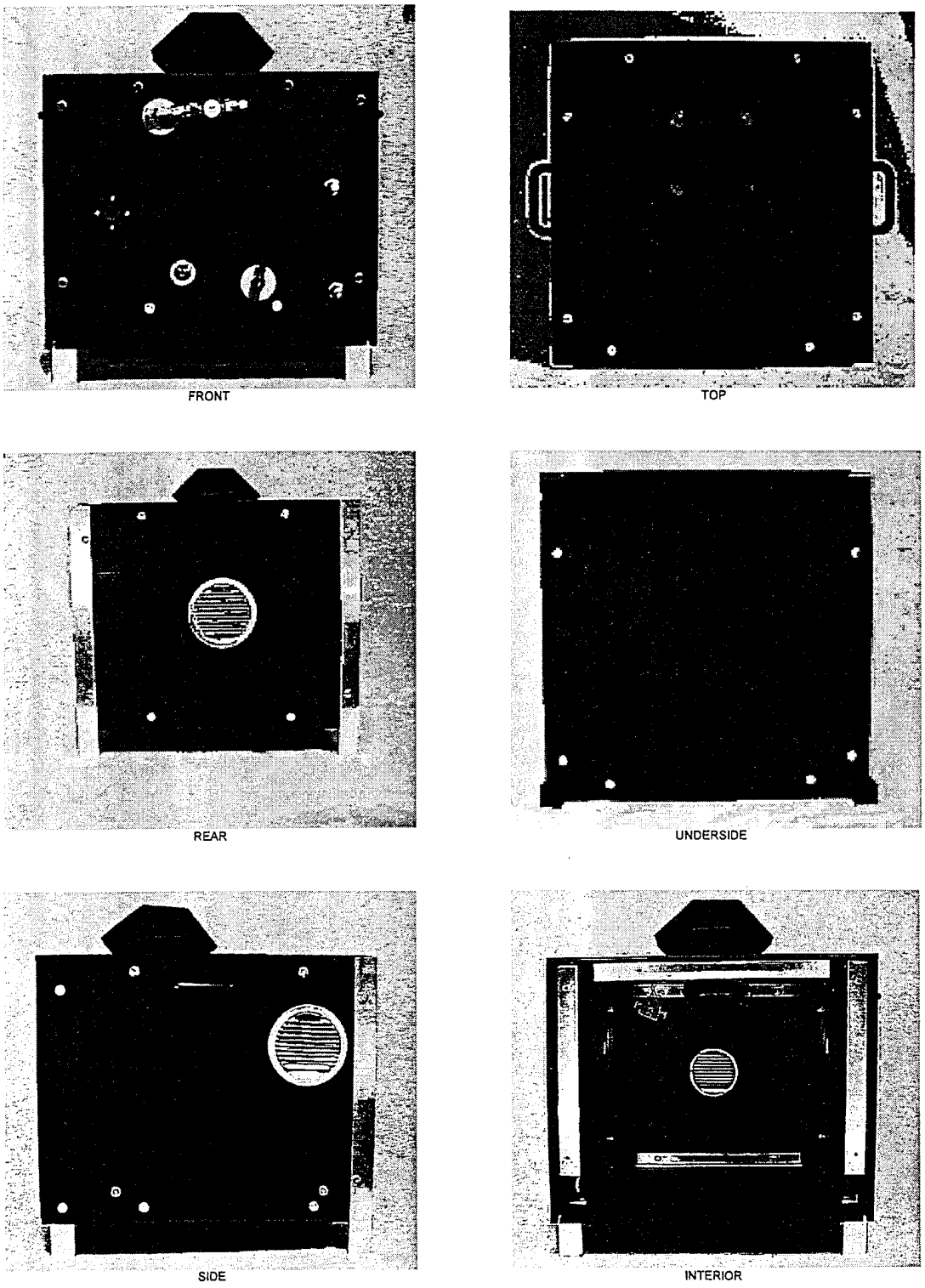
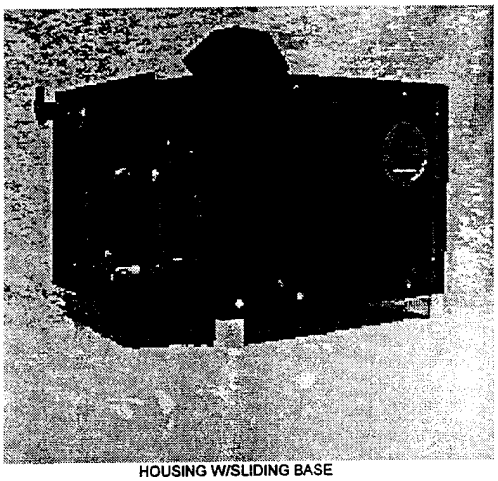
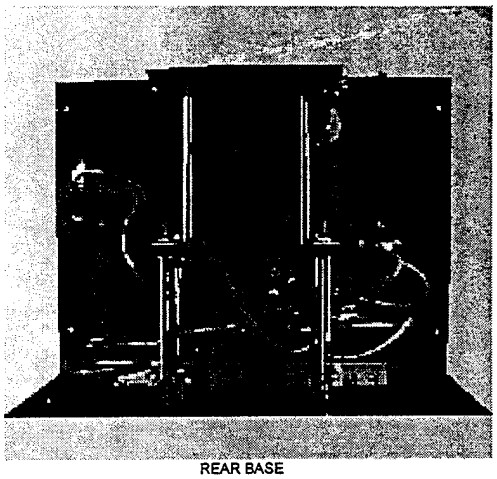


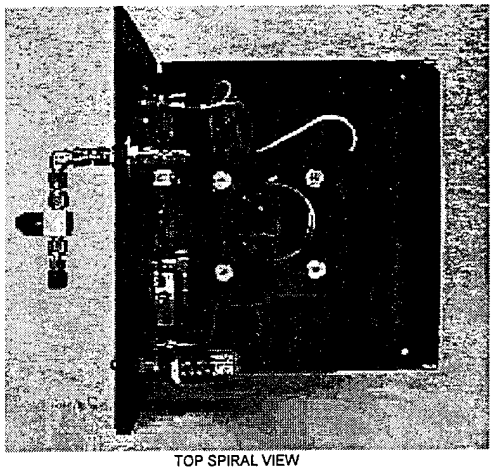
Figure 7: Different Views of the Separation Unit



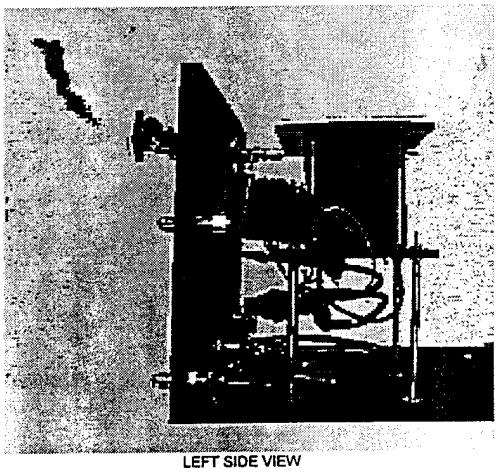
HOUSING W/SLIDING BASE



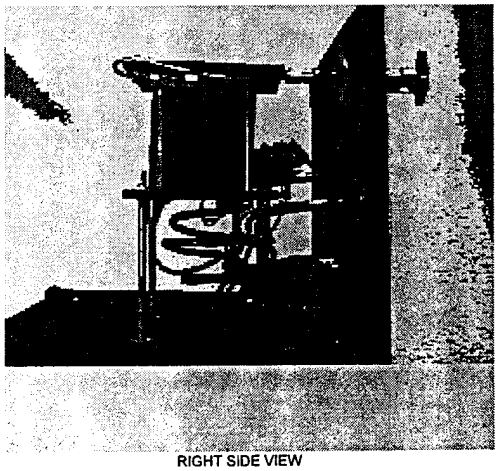
REAR BASE



TOP SPIRAL VIEW



LEFT SIDE VIEW



RIGHT SIDE VIEW

Figure 8: Different Interior Views of the Monitor

1.9: Material Lists for the Separation Unit and Controller

Table 2: SEPARATOR UNIT HOUSING MATERIALS LIST		
Qty	Part Description	Vendor
Components		
6 ft^2	PVC Sheets (6 mm thickness)	U. S. Plastics
1	3" Diameter Vent Cap	Home Depot
3	3" Diameter Louvers	Home Depot
1	Papst Variofan (Model # 8412 GMV)	Allied Electronics
2	Carrying Handles	Home Depot
4	Teflon Spacers	Home Depot
1 male/ 1female	4 Conductor Molex Connector	Radio Shack
1 set	Runners (1' length)	Home Depot
Fasteners		
48	3/8" Screw Posts	Home Depot
8 ft.	1/8" X 3/4" Aluminum Angle	Home Depot
5 ft.	1/8" X 1" Aluminum Angle	Home Depot
6	8/32" Socket Cap Screw @ 1/2" length	Home Depot
6	8/32" Finishing Washers	Home Depot
8	8/32" Machine Screw Nuts	Home Depot
4	8/32" Machine Screws @ 1" length	Home Depot
Components		
2.5 ft.	1/4" O.D. Stainless Steel Tubing	Supelco
5.5 ft.	1/4" O.D. Copper Tubing	Henri's Hardware
1 ft.	1/8" O.D. Stainless Steel Tubing	Supelco
1	Negative Temp. Coefficient Thermistor	Allied Electronics
1	Temperature Controller	Allied Electronics
1	3" PVC Pipe	Home Depot

Table 2: SEPARATOR UNIT HOUSING MATERIALS LIST		
Qty	Part Description	Vendor
1	Sporlan Moisture & Liquid Indicator (1/4" SAE Flare Male X 1/4" SAE Flare Female)	United Refrigeration
1	NUPRO Plug Valve (316 SS 1/4 " Swagelok)	Georgia Valve
1	NUPRO Screw Bonnett Needle Valve	Georgia Valve
4 ft.	8/32" Threaded Rod	Henri's Hardware
Fasteners		
2	Brass AN Bulkhead Union (1/4" Flare to 1/4" Swagelok)	Georgia Valve
3	1/2" X 1 1/2" Fender Washers	Home Depot
4	8/32" Machine Nuts	Home Depot
2	1/4" Port Connectors	Georgia Valve
4	1/4" Nut	Georgia Valve
1	1/4" AN Adapter with nut	Georgia Valve
8	8/32" Anchor Nuts	Home Depot
12	8/32" Washers	Henri's Hardware
1	1/4" to 1/8" Reducing Union	Georgia Valve
1	316 SS AN Bulkhead Union (1/4" Flare to 1/4" Swagelok)	Georgia Valve
4	SAE 1/4" Flare Nuts	Henri's Hardware
1	SAE 1/4" Flare Tee	Henri's Hardware
1	316 SS 1/4" Swagelok Union Elbow	Georgia Valve
1	316 SS 1/4" Swagelok to Flare AN Union	Georgia Valve
1	1/2" Copper Pipe Holder	Home Depot

Table 3: Controller Parts List		
Qty	**Part**	**Description**
Probes		
2	MTS102	Silicone Temperature Sensor
Board 1		
1	LM324	Quad Low Power Operational Amplifier
1	AD830	High Speed Video Difference Amplifer
1	HE722A0610	Reed Relay DPST-NO with diode suppressor
1	1k Potentiometer	15 turn
1	100k Potentiometer	15 turn
1	100 Ω	1%
1	499 Ω	1%
4	1 kΩ	1%
1	2k Ω	1%
3	10 kΩ	1%
1	20 kΩ	1%
1	100 kΩ	1%
1	1 MΩ	**10%**
1	.1μ Farad	Tantalum
2	.01μ Farad	Tantalum
Board 2		
3	LM339	Quad Comparator
16	100 Ω	**10%**
11	10 kΩ	**10%**
1	1 kΩ Potentiometer	15 turn
Board 3		
1	LM339	Quad Comparator
1	MC14536BCP	Programmable Timer
2	HE722A0610	Reed Relay DPST-NO with diode suppressor
2	100 Ω	**10%**
2	301 Ω	**10%**
5	5.11 kΩ	**10%**
1	10 kΩ	**10%**
1	51.1 kΩ	**10%**

Table 3: Controller Parts List		
Qty	**Part**	**Description**
1	75 kΩ	**10%**
1	.22 μF	Tantalum
Face Plate		
1	Binary Coded Hexadecimal Switch	Grayhill 26 series switch
1	DPM-1	3 ½ Digit Subminiture Meter
1	SPDT Switch	Momentary Rocker Switch
5	Green LED's	
2	Yellow LED's	
2	Red LED's	
1	Flashing Red LED	
Rear Plate		
1	Piezo Annunciator	4-28vdc 3-18ma
1	On/Off Switch	Rocker Switch
1	5 Pin Din Jack	
1	Amp Jack	Series 2 11-8
Miscellaneous		
1	Case	
3	Pc Baords	
6	Buss Bars	
1	WRI 2731 Power Supply	+5v, -12v, +12v @47-63Hz & 95-250vac
1	Connecting Cable (Amp)	25ft